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RESEARCH ARTICLE

Upper nasal hemifield location and nonspatial auditory tones accelerate visual detection during dichoptic viewing

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Abstract

Visual performance is asymmetric across the visual field, but locational biases that occur during dichoptic viewing are not well understood. In this study, we characterized horizontal, vertical and naso-temporal biases in visual target detection during dichoptic stimulation and explored whether the detection was facilitated by non-spatial auditory tones associated with the target's location.

The detection time for single monocular targets that were suppressed from view with a 10 Hz dynamic noise mask presented to the other eye was measured at the 4˚ intercardinal location of each eye with the breaking Continuous Flash Suppression (b-CFS) technique. Each target was either combined with a sound (i.e., high or low pitch tone) that was congruent or incongruent with its vertical location (i.e., upper or lower visual field) or presented without a sound. The results indicated faster detection of targets in the upper rather than lower visual field and faster detection of targets in the nasal than temporal hemifield of each eye. Sounds generally accelerated target detection, but the tone pitch-elevation congruency did not further enhance performance. These findings suggest that visual detection during dichoptic viewing differs from standard viewing conditions with respect to location-related perceptual biases and crossmodal modulation of visual perception. These differences should be carefully considered in experimental designs employing dichoptic stimulation techniques and in display applications that utilize dichoptic viewing.

Introduction

Visual perception is asymmetric across the visual field. Visual performance is known to generally decrease with increasing distance from the fovea due to losses in the contrast sensitivity and spatial resolution of the eye [1], but performance consistently varies across the visual field, even at isoeccentric locations. Indeed, a number of studies demonstrate performance differences for equidistant stimuli presented in the left and right visual fields, upper and lower visual fields, and temporal and nasal hemifields of the eyes [2±12]. However, because these performance asymmetries have been defined under standard viewing conditions, in which stimuli are viewed either binocularly or monocularly, the results do not necessarily comply with dichoptic viewing, during which both eyes are simultaneously presented with different stimuli. The present study aims to clarify this largely unexplored topic by investigating spatial biases in target detection during dichoptic viewing and the influence of crossmodal cueing on detection performance with a dichoptic stimulation technique known as Continuous Flash Suppression (CFS; [13]).

When an observer's right and left eye are presented with dissimilar images at corresponding retinal locations, the images cannot be fused and the conscious percept varies between the two alternatives. This phenomenon, known as *binocular rivalry*, is characterized as a random alternation of dominance and suppression phases between the two eyes [14]. At a given moment during dichoptic viewing, the observer only perceives the stimulus presented to the dominant eye, whereas the stimulus presented to the suppressed eye remains outside conscious perception. Although the mechanisms that control the alteration of the suppression and dominance phases are not fully understood [14,15], research has shown that the ability of a stimulus to break suppression, in other words, to become detected, is strongly defined by low-level visual features, such as contrast, orientation, and spatial frequency [16,17]. However, another fundamental feature that is likely to modify the stimulus strength under dichoptic stimulation is the location of the target in the visual field.

Research on location-based biases in visual performance suggest that horizontal, vertical, and naso-temporal asymmetries originate from different stages of the visual processing stream. Most horizontal asymmetries (left vs. right visual field) reflect the lateral specialization of the two hemispheres. Because the left hemisphere is more sensitive to local features and high spatial frequencies and the right hemisphere is sensitive to global features and low spatial frequencies, high-frequency stimuli are more likely to bias perception rightwards and low-frequency stimuli are more likely to bias perception leftwards [3,18]. A horizontal bias may also indicate an uneven distribution of spatial attention, as performance in many attention-demanding visual tasks is biased toward the left side of space [19]. This leftward bias may result from the higher involvement of the right hemisphere in tasks that require visuospatial attention [20] or the left-to-right scanning strategy that resembles reading text in Western languages [21].

Vertical asymmetries (upper vs. lower visual field) greatly depend on the requirements of the visual task. Stimulus discrimination is more efficient in the lower than upper visual field [5,8,11,12], which is in line with anatomical asymmetries in the retina [22,23] and lateral geniculate nucleus (LGN) [24]. A lower visual field bias has also been found for tasks that require focused sustained attention, including conjunction search and multiple object tracking [25], as well as attentional tasks that require object individuation [26]. In contrast to these downward biases, an upward bias is common for tasks that require attention guidance, such as a visual search [7,27], or semantic processing, including categorical judgments [6,28]. It thus appears that subcortical and early cortical visual processes tend to bias perception downwards, whereas attention may bias performance either downwards or upwards depending on the task demands.

However, the most intriguing asymmetry in the context of the present study is the bias between the retinal hemifields (nasal vs. temporal) as the direction of the bias under standard viewing conditions seems to contradict the findings of dichoptic viewing. Under standard viewing conditions, visual processing is more efficient in the temporal hemifield than nasal hemifield of the eye, as demonstrated by sensitivity thresholds [10,12], reaction times [9], and electrophysiological recordings [12]. This temporal hemifield bias is associated with anatomical asymmetries in the retina [22,23] and superior colliculus (SC) of the midbrain [29]. By contrast, two binocular rivalry studies have previously demonstrated longer dominance durations for stimuli presented to the nasal hemifield of an eye (i.e., temporal hemiretina; Fig 1) compared to stimuli presented to the temporal hemifield (i.e., nasal hemiretina) [30,31] under